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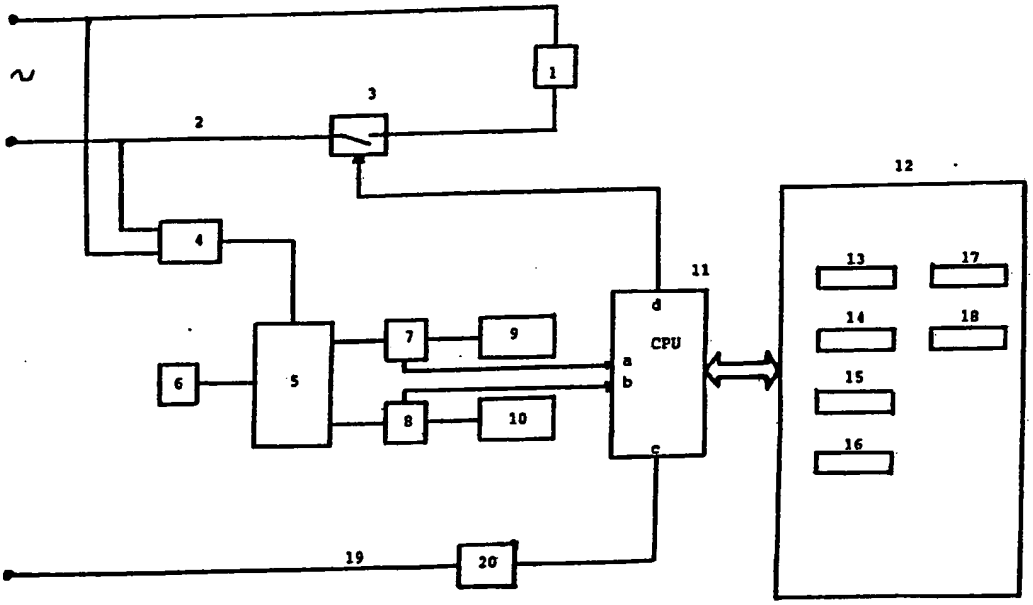
(54) Title: ELECTRICAL LOAD SHEDDING CIRCUIT



(57) Abstract

An apparatus for controlling the load of an alternating-current electricity supply system supplying power to a plurality of consumers. At each consumer's premises the load (1) is connected to an AC mains (2) via a controllable load switch (3). Across the mains is coupled a frequency measuring means (4, 5 and 6) whose output is compared in comparators (7, 8) with predetermined threshold values stored in limit registers (9, 10). The threshold values correspond to frequencies below the normal frequency of the power supplied. When a threshold value is exceeded due to a fall in frequency, an interrupt signal is provided at the output of one or other comparator, depending on the severity of the fall in frequency. The interrupt signal is extended to an input of a processor (11) which operates the load switch after a predetermined delay provided by delay registers (13, 14) associated with the comparators, and disconnects the load from the mains.

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Electrical Load Shedding Circuit

Technical Field

This invention relates to emergency load shedding means for AC electricity power supply systems supplying power to a plurality of consumers.

In such systems when power demand exceeds supply the generators providing the power to the system become overloaded. This overload may occur rapidly and it is necessary to shed non-essential loads quickly in order to avoid a collapse of the entire system.

Background Act

In a known method to reduce demand on an electricity supply system in the event of power demand exceeding supply, a command signal is transmitted from the power utility's control centre to a remotely operated switch at the consumers premises, turning off non-essential loads such as large capacity hot water heaters, swimming pool filters etc.

A major problem with such a method, however, is the amount of time taken to transmit the command signal to the consumers premises which may take up to several minutes and require a relatively complex communication link. Under emergency conditions, such as the loss of a generator, the power begins to drop immediately, possibly leading to a collapse of the system before commands can be issued to turn off the non-essential loads. One known system devised to solve this problem utilizes the drop in supply frequency, hereinafter referred to as an under-frequency, which occurs when a generator becomes overloaded. By detecting a drop in the supply frequency at a substation the load of a whole suburb is shed. This causes great inconvenience to the consumers affected.

Another known system, described in the specification of Australian Patent No. 542,286 provides a device at the consumers premises which, if a phase-lock loop fails to maintain synchronization between a clock signal generator and the incoming waveform of the AC supply, produces a phase er-

ror signal which is used to control switching means to shed at least part of the load at the consumer's premises.

A disadvantage of the last mentioned known system is that the lock range of the phase lock loop is determined by analogue components whose tolerances do not permit the accurate setting of the threshold frequency in a reproducable way. Moreover, the threshold frequency must be set during manufacture and cannot be easily altered.

It is therefore an object of the present invention to provide a method and device for controlling the load of an AC electricity supply system in which the threshold frequencies can be set precisely using standard components.

It is a further object of the present invention to provide a method and device for controlling the load of an AC electricity supply system whose threshold frequencies are programmable during manufacture, on site or remotely.

A still further object of the present invention is to provide a method and device for controlling the load of an AC electricity supply system which may employ a simple telephone line as a link to the utility command centre.

Summary of the Invention

According to a first aspect of the invention there is provided a method of controlling the load of an alternating-current electricity supply system supplying power to a plurality of consumers, said method comprising the steps of, for each of the plurality of consumers, measuring the frequency of the alternating-current supply, comparing the measured frequency to at least one threshold value stored in storage means which corresponds to a predetermined frequency below the normal frequency of the supplied voltage, and upon the measured frequency falling below said threshold value causing, after a predetermined delay, at least part of the consumers lead

to be disconnected from the said supply system, said load being re-connected to the said supply system when the measured frequency has risen above said threshold value.

According to a further aspect of the invention there is provided an apparatus for use by a consumer using power for a load from an alternating-current electricity supply system supplying power to a plurality of consumers, comprising frequency measuring means arranged to measure the frequency of the alternating-current supply and provide a frequency output signal indicative of the measured frequency, comparison means to which said frequency output signal is applied and which compares said frequency output signal to at least one threshold value, said threshold value corresponding to a first predetermined frequency which is below the normal frequency of said alternating current supply, wherein when said frequency output signal indicates that the measured frequency has fallen below said one threshold value, a switch control signal is provided by said comparison means after a first predetermined disconnect delay provided by disconnect delay means, said switch control signal being extended to a load switch means which is rendered non-conducting thereby to disconnect at least part of said consumer's load from the said supply means, said load switch means being rendered conducting upon said measured frequency rising above said threshold value, thereby re-connecting said at least part of said consumers load to the said supply system.

The present invention ensures, that if an under-frequency condition occurs, electrical loads are shed before load-shedding commands could be issued over conventional load-control systems. Load-shedding is achieved with the present invention on a priority basis, by dropping first non-essential loads, and then more important loads for successively more severe failures, reducing network load before indiscriminate (suburb-wide) blackouts occur.

Best Mode of Carying Out The Invention

In order that the invention can be readily understood, an embodiment thereof will now be described in relation to the figure of the drawing.

Referring to the drawing, a load 1 is connected to an AC mains 2 via a load switch 3. Across mains 2 is coupled a zero-crossing detector 4 whose output is coupled to an input of a counter means 5 associated with a crystal oscillator 6. Outputs of counter means 5 are respectively connected to inputs of comparator means 7 and 8 each of which is associated with respective limit register means 9 and 10. Respective outputs of comparator means 7 and 8 are connected to inputs a and b of processor means (CPU) 11.

A memory 12 associated with processor 11 includes four delay registers 13, 14, 15 and 16 and two memory registers 17 and 18 respectively associated with delay registers 13 and 14.

An output of processor 11 is coupled to load switch 3. A phone line 19 is connected to an input c of processor means 11 via an interface means 20 for connection to the power utility's System Control and Data Aquisition (SCADA). Alternatively, the AC mains or a radio link could be utilized for providing the connection to SCADA.

It will be understood, that although the preferred embodiment includes a connection to the power utility's SCADA, the load control arrangement of the present invention can be programmed to operate independently of commands for SCADA in which case interface 20 and phone line 19 would not be needed.

In operation the frequency of the power supply on mains 2 is monitored by zero crossing detector 4, which produces a pulse every time the power supply waveform passes through zero, producing nominally 100 or 120 pulses per second for 40Hz or 60Hz respectively. Preferably, the zero-crossing detector is filtered in hardware (not shown) to reduce the incidence of

spurious outputs due to noise impulses on mains 2 or voltage harmonics, which can both produce spurious zero-crossings.

A counter 5 is continually incremented by crystal oscillator 6 at a rate which will preferably count at least 1000 counts per AC cycle, giving a resolution of better than 0.01 ms. This provides a fine control over the order of shedding different types of load. Counter 5 is reset by a pulse from zero-crossing detector 4 twice for every AC cycle. The value of the output of counter 5 is continually compared in comparator means 7 and 8 to threshold values programmed into two limit registers 9 and 10 respectively associated therewith. A threshold value corresponding to a severe under-frequency is contained in limit register 10 and a threshold value corresponding to a less severe under-frequency is contained in limit register 9.

When the threshold value is exceeded in limit register 9 due to a less severe under-frequency, an interrupt signal is provided at the output of the comparator means 7. This signal is extended to input a of the processor means 11 which prepares to operate load switch 3 and shed load 1.

To ensure that load 1 is not shed prematurely due, for example, to an occasional noise impulse or single cycle power loss, the processor means includes filter means in the form of software. Two delay registers 13 and 14 are provided in a memory 12 associated with the processor means. In the case of an interruption of a less severe under-frequency condition, a "1" is added to delay register 13. The delay register is decreased at regular intervals, for example, by 1 every 40 ms. The processor means waits until the count exceeds the preset maximum value stored in memory register 15 associated with delay register 13. Typically, this maximum value is 1750 which causes a delay of about 25 seconds at 50 Hz. This method imposes no interrupt load on the processor means software until an under-frequency condition occurs. After 25 seconds, the processor means operates load switch 3 and sheds load 1.

Similarly, when the threshold value programmed in limit register 10 is exceeded, due to a severe under-frequency, an interrupt signal is provided at the output of comparator means 8. This signal is extended to input b of the processor means which prepares to operate the load switch 3 and shed load 1. The processor means waits until the count in the delay register 14 exceeds the preset maximum value stored in memory register 18 associated with the delay register 14. Typically, the maximum value is 10 resulting in a delay of about 150 ms at 50 Hz. After 150 ms the processor means operates the load switch 3 and sheds load 1.

After the AC frequency returns to above the threshold determined by register 14 the processor 11 switches load switch 3 and restores power to load 1. Restoration, however, only occurs after a delay. Delay registers 15 and 16 provide a maximum and minimum delay time limit and processor 11 selects a delay within those limits. Typically the minimum delay is 5 minutes and the maximum delay is 10 minutes. This allows the highest priority loads to be switched to the supply quickly, and the lowest priority loads remain shed for a longer period. This delay may be selected randomly to prevent all loads being restored simultaneously. The delay also allows sufficient time for the SCADA system to transmit overriding commands over telephone line 17 if required. The load may be restored or restoration inhibited by these commands.

The power utility's SCADA system coupled to phone line 17 is programmed with the characteristics of all non-essential loads controlled by the load shedding arrangement of the present invention. The under-frequency limit values are programmed into each limit register 9 and 10 and delay registers 13 and 14 for the type of load controlled by these registers which allows gradual load shedding as the power is lost. The registers may be programmed remotely via phone line 17, or via the supply line 2 or manually during manufacture, or later on site.

Processor means 11 may form part of an energy management terminal such as, for example, the one described in Australian Patent Application No. 65,908/86.

Although two limit registers are shown in the preferred embodiment, further limit registers may be included to provide further frequency/delay profiles for a single load, or provide respective under-frequency thresholds for a plurality of loads.

In an AC electricity power supply system whose normal frequency is 50 Hz, the threshold values programmed in the limit registers may be :

1. Less severe under-frequency condition : 49.0 Hz for 25 seconds
2. Severe under-frequency condition : 48.5 Hz for 150 ms.

The less severe under-frequency condition might occur, say, during a cold snap when many consumers switch on electrical heating apparatus. The load increases gradually and the frequency of the power supply correspondingly falls. If it reaches 49.0 Hz and remains there for at least 25 seconds load shedding commences.

The severe under-frequency condition might occur in the event of a generator failing. Under this condition the load rapidly exceeds supply and there is a corresponding rapid fall in the power supply's frequency to 48.5 Hz. After 150 ms the load shedding commences.

While the present invention has been described with regard to many particulars, it is to be understood that equivalents may be readily substituted without departing from the scope of the invention.

The claims defining the invention are as follows:

1. A method of controlling the load of an alternating-current electricity supply system supplying power to a plurality of consumers, said method comprising the steps of, for each of the plurality of consumers, measuring the frequency of the alternating-current supply, comparing the measured frequency to at least one threshold value stored in storage means which corresponds to a predetermined frequency below the normal frequency of the supplied voltage, and upon the measured frequency falling below said threshold value causing, after a predetermined delay, at least part of the consumers lead to be disconnected from the said supply system, said load being re-connected to the said supply system when the measured frequency has risen above said threshold value.

2. A method as claimed in claim 1, including the step of delaying for a predetermined time the re-connexion of the at least part of the consumers load to the said supply system.

3. A method as claimed in claim 2, wherein the re-connexion of at least part of the consumers load is selectively determined by command signals transmitted from a remote control centre via a communications link.

4. An apparatus for use by a consumer using power for a load from an alternating-current electricity supply system supplying power to a plurality of consumers, comprising frequency measuring means arranged to measure the frequency of the alternating-current supply and provide a frequency output signal indicative of the measured frequency, comparison means to which said frequency output signal is applied and which compares said frequency output signal to at least one threshold value, said threshold value corresponding to a first predetermined frequency which is below the normal frequency of said alternating current supply, wherein when said frequency output signal indicates that the measured frequency has fallen below said one threshold value, a switch control signal is provided by said comparison

means after a first predetermined disconnect delay provided by disconnect delay means, said switch control signal being extended to a load switch means which is rendered non-conducting thereby to disconnect at least part of said consumer's load from the said supply means, said load switch means being rendered conducting upon said measured frequency rising above said threshold value, thereby re-connecting at least part of said consumers load to the said supply system.

5. An apparatus as claimed in claim 4, wherein said frequency output signal is compared to a further threshold value which corresponds to a second predetermined frequency below the first predetermined frequency, and wherein when said frequency output signal indicates that the measured frequency has fallen below said further threshold value a switch control signal is provided by said comparator means after a second predetermined disconnect delay provided by the disconnect delay means, said second predetermined delay being shorter than said first delay means, said switch control signal being applied to said load switch means which is rendered non-conducting thereby to disconnect at least part of said consumer's load from the said supply system.

6. An apparatus as claimed in claims 4 or 5 including re-connect delay means arranged to delay said re-connexion of at least part of said consumer's load for a predetermined period.

7. An apparatus as claimed in any one of the preceding claims, wherein each threshold value is stored in a respective limit register means associated with a comparator means.

8. An apparatus as claimed in claim 7, wherein said limit register means are programmable.

9. An apparatus as claimed in any one of claims 4 to 8, wherein said disconnect delay means comprises first and second delay register means each

associated with memory means to provide first and second predetermined disconnect delays.

10. An apparatus as claimed in claim 9, wherein said first and second disconnect delay register means are programmable.

11. An apparatus as claimed in any one of claims 6 to 10 wherein said re-connect delay means comprise third and fourth delay register means to provide first and second predetermined re-connect delays.

12. An apparatus as claimed in claim 11, wherein said third and fourth delay register means are programmable.

13. An apparatus as claimed in claim 11 or 12, wherein said third and fourth delay register means provide respectively minimum and maximum re-connexion delay limits, for providing a selectable delay within said limits.

14. An apparatus as claimed in any one of claims 9 to 13, wherein said disconnect delay means includes additional delay register means and associated memory means.

15. An apparatus as claimed in any one of claims 11 to 14, wherein said re-connect delay means includes additional delay register means.

16. An apparatus as claimed in claim 14 or 15 wherein the additional delay means are programmable.

17. An apparatus as claimed in any one of claims 4 to 15, including processor means to whose input means is coupled to said switch control signal and processed therein, an output of said processor means being coupled to said load switch means for controlling the load switch means with a control signal produced in said processor means.

18. An apparatus as claimed in claim 17, wherein a communications line is coupled to a still further input of said processor means, whereby command signals from a remote control means coupled to the communication line

are processed for overriding or delaying the re-connexion of at least part of said consumer's lead.

19. An apparatus as claimed in claim 17 or 18, wherein said limit register means and/or said delay register means are remotely programmable via said communications line.

20. An apparatus as claimed in any one of claims 17 to 19, wherein said processor means is incorporated in an energy management terminal means.

21. An apparatus as claimed in claim 20, wherein said remote control emans is a system control and data aquisition (SCADA) means.

22. An apparatus as claimed in any one of claims 18 to 21 wherein said communication line is a telephone line.

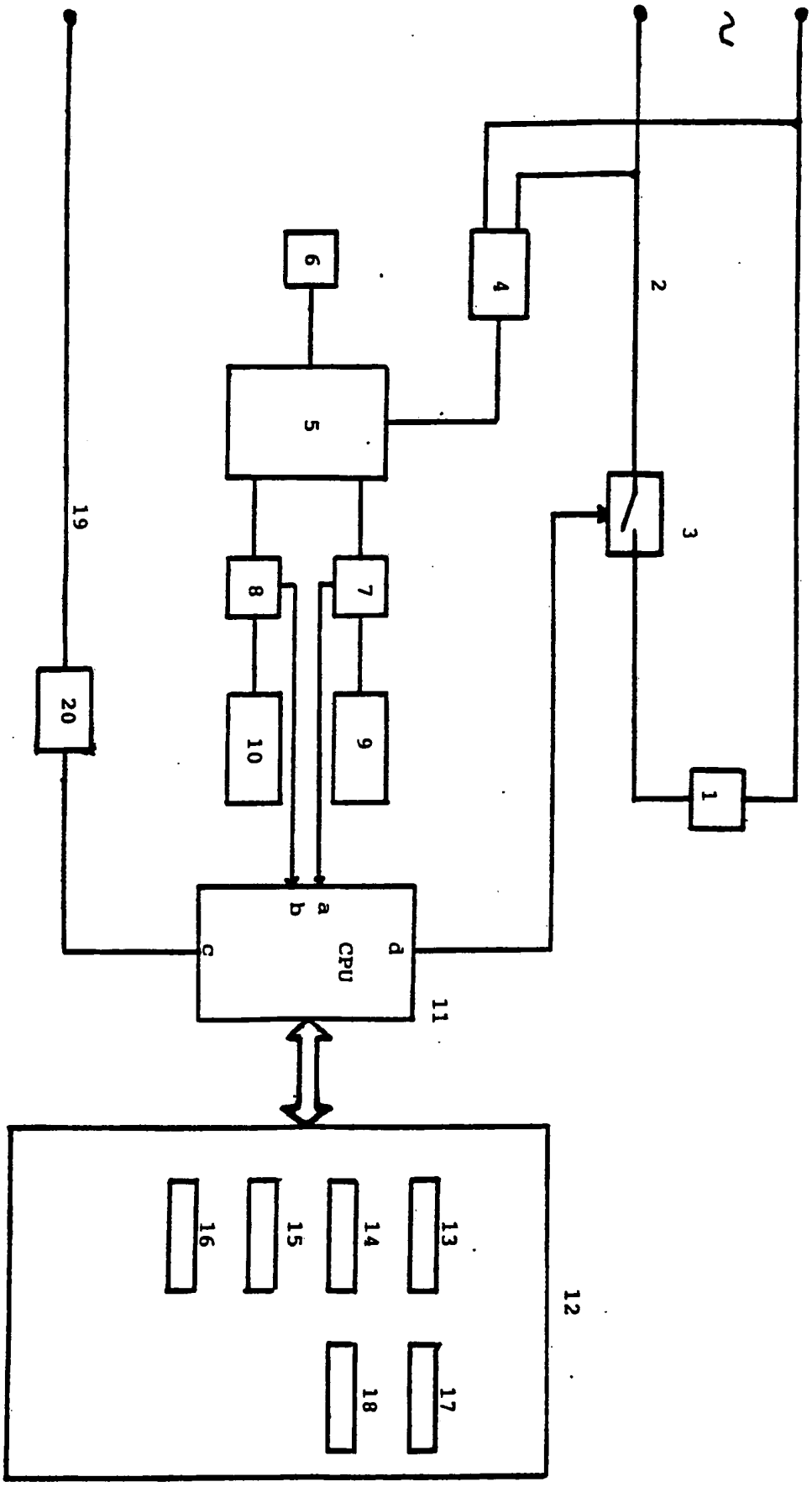
23. An apparatus as claimed in any one of claims 18 to 21, wherein said communication line is provided by the AC mains.

24. An apparatus as claimed in any one of claims 17 to 23, wherein said processor means incorporates filter means adapted to filter noise impulses and single cycle losses.

25. An apparatus as claimed in any one of claims 4 to 24, wherein said frequency measuring means comprises an arrangement which counts pulses from an oscillator means that occur between successive zero-crossings of the alternating current's waveform, the count being applied to said comparator means and compared to said threshold values.

26. An apparatus as claimed in claim 25, wherein said oscillator means comprises a crystal controlled oscillator.

27. An apparatus for use by a consumer using power for a load from an alternating current electricity supply system, substantially as herein described with reference to the figure of the drawing.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INTERNATIONAL SEARCH REPORT

International Application No PCT/AU 89/00006

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int. Cl.[4] H02H 3/46, 3/06

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC	H02H 3/46, 3/06

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

AU : H02H 3/46, 3/06, H04B 3/54, H02J 13/00

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category *	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
Y	Derwent Abstract Accession No. K9715B/47, Class R51, SU,A, 650156 (CASIA BR ENERGOSET) 28 February 1979 (28.02.79) & US,A, 3906242 (STEVENSON) 16 September 1975 (16.09.75)	(1-6)
Y	Derwent Abstract Accession No. A1644C/01, Class R51, SU,A, 657501 (CASIA ENERGOSETPRO) 18 April 1979 (18.04.79) & SU,A, 650156 & US,A, 3906242	(1-6)
Y	AU,B, 72718/81 (542286) (SOUTH EASTERN ELECTRICITY BOARD) 21 January 1982 (21.01.82) & SU,A, 650156 & US,A, 3906242	(1-6)
Y	GB,B, 695816 (NATIONAL RESEARCH DEVELOPMENT CORP.) 19 August 1953 (19.08.53) & SU,A, 650156 & US,A, 3906242	(1-6)
Y	GB,B, 629359 (WHITBY) 8 November 1949 (08.11.49) & SU,A, 650156 & US,A, 3906242	(1-6)
A	GB,B, 712824 (THE ELECTRICAL APPARATUS CO. LTD) 4 August 1954 (04.08.54)	
A	Derwent Abstract Accession No. L1181D/43, Class X13, SU,A, 792403 (CASIA ENERGOSETPRO) 30 December 1980 (30.12.80)	

(continued)

* Special categories of cited documents: [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
2 March 1989 (02.03.89)	9 MARCH 1989 (09.03.89)
International Searching Authority	**Signature of Authorized Officer**
Australian Patent Office	R.A. MURRAY

Form PCT/ISA/210 (second sheet) (January 1985)

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

A	Derwent Abstract Accession No. E4437B/20, Class R51, SU,A, 614486 (CENTRAL ASIA ENERGO) 26 June 1978 (26.06.78)	
A	AU,A, 46289/85 (STOLP et al) 20 February 1986 (20.02.86)	
A	AU,B, 74729/81 (553281) (PEDDIE et al) 11 March 1982 (11.03.82)	
A	DE,A, 2906460 (VILLAMOSENERGIAIPARI) 30 August 1979 (30.08.79)	

V. ☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE [1]

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1. ☐ Claim numbers....., because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claim numbers....., because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claim numbers....., because they are dependent claims and are not drafted in accordance with the second and third sentences of PCT Rule 6.4(a).

VI. ☐ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING [2]

This International Searching Authority found multiple inventions in this international application as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4. ☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.

☐ No protest accompanied the payment of additional search fees.

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON

INTERNATIONAL APPLICATION NO. PCT/AU 89/00006

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report	Patent Family Members		
AU 72718/81	CA 1166310	EP 44181	GB 2080640
	JP 57049332	NZ 197667	US 4385241
AU 74729/81	CA 1179404	EP 47089	GB 2083301
	JP 57075322	NZ 198094	US 4471232
DE 2906460	SE 7901408	YU 398/79	
US 3906242	CA 1025049	CH 607807	FR 2282181
	GB 1519174	US 4023043	

END OF ANNEX